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WAVELENGTH SELECTIVE SWITCH

Technical field of the invention

The present invention relates to a wavelength selec-
tive optical switch. More particularly, the present in-
5   vention relates to methods and devices for coupling indi-
vidual channels within a wavelength division multiplexed
optical signal from one optical fiber to another optical
fiber.

Technical background and related art

10   In order to increase the transmission capacity of
optical fiber networks and communication links, wave-
length division multiplexing (WDM) techniques are often
utilized. In WDM systems, a plurality of wavelength chan-
nels is transmitted through a single optical fiber. Fi-
15   bers are connected at points known as "nodes", at which
channels are rerouted towards their final destinations
via the best possible fiber paths. Channels may also be
added or dropped at so called add/drop points. Generally,
20   at the nodes the WDM-signal is demultiplexed, the indi-
vidual signals re-routed and sent down the chosen fiber,
possibly multiplexed into another WDM signal. At add/drop
points, spectrally selective optical switches, also known
as channel drop filters, are utilized for extraction of a
25   single wavelength channel from a WDM signal, or for in-
sertion of a single wavelength channel into a WDM signal.
The network may be designed to be either static or
re-configurable. A re-configurable network is essential
to provide provision of wavelengths and enable protection

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switching. In a re-configurable network, the nodes and/or
add/drop points are equipped with switches or dynamic
wavelength converters, giving it the capability to change
the routing pattern.

5   A technology used to enable optical rerouting are
MEMS switches, which utilizes small moveable mirrors dis-
placeable to dispatch the optical signal to the chosen
fiber. Such an optical switch is presented in US
6,292,281, in which a matrix of mirrors are provided on a
10   silicon wafer based structure. Also, the nodes may be
provided with add-drop filters designed to add or drop a
specific chosen channel to or from the WDM channel.

However, the prior art technology suffers from sev-
eral drawbacks. Optical MEMS switches are complicated and
15   difficult to manufacture, and are devices that require
de-multiplexing and multiplexing of the WDM signal.

Therefore, there is a need for devices and methods
for coupling individual channels within a WDM signal from
one fiber to another enabling an easily re-configurable
20   and dynamic network.

Summary of the invention
        The present invention provides an optical wavelength
selective switch, which eliminates, or at least allevi-
25   ates, the aforementioned problems in the prior art.
        A general object of the present invention is to pro-
vide an optical device for coupling one or more individ-
ual signals propagating in one fiber to another fiber.
This general object is achieved by a device, arrangement
30   and method according to the appended claims.
        According to a first aspect the invention, a device
is provided, comprising a first and a second optical
waveguide, each having a light guiding structure arranged

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to guide light along a predetermined path, the optical
waveguides being arranged adjacent and parallel to each
other. Furthermore the device comprises an external reso-
nator defined by a first and a second mirror, said first
5   and said second mirror being provided on opposite sides
and outside of said first and second light guiding struc-
tures, and said external resonator being resonant to a
specific wavelength. Finally there is in each waveguide
provided a deflector, which is arranged to deflect light
10   propagating in one of the light guiding structures to the
other light guiding structure by operation of said exter-
nal resonator.

    According to another aspect of the invention, the
device comprises means for adjusting resonator wavelength
15   and phase of the chosen channel to affect.

    In yet another aspect, the present invention can
serve as an add/drop filter. Individual WDM channels may
conveniently be added or dropped by a respective channel
manipulation element. Yet another field of use for the
20   optical device according to the present invention is in
connection with fiber-to-fiber routers, where the present
invention can provide channel exchange between two trans-
mission fibers or fiber rings.

    Moreover, the present invention provides other fea-
25   tures and advantages that will become apparent when the
following detailed description of some preferred embodi-
ments is read and understood.

Brief description of the drawings

30   In the following, a number of preferred embodiments
of the present invention will be described in detail. The
description below is more easily understood when read in
conjunction with the drawings, in which

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figure 1 schematically shows a first embodiment of a basic optical switch element according to the present invention;

figure 2 schematically shows an embodiment of a
5   cleaning device that may advantageously be used together with the switch element;

figure 3 schematically shows an embodiment of a add/drop device using an array of switch elements;

figure 4 schematically shows another embodiment of a
10 add/drop device using an array of switch elements;

figure 5 schematically shows yet another embodiment of a add/drop device using an array of switch elements;

figure 6 schematically shows yet another embodiment of a add/drop device using an array of switch elements;

15   figure 7 schematically shows an switch device incorporating a switch controller; and

figures 8-12 3 schematically shows embodiments of various switch arrangements.

20 <u>Detailed description of preferred embodiments</u>

A first preferred embodiment of an optical switch element 1 according to the present invention is schematically shown in figure 1. The arrangement shown is to be regarded as the best mode of carrying out the invention. The switch
25 element is used to switch an optical signal from one optical fiber to another optical fiber. This element fundamentally is simultaneously wavelength selective, wavelength tunable and array cascadable.

The switch element 1 comprises a first optical fiber
30 or waveguide 2 and a second optical fiber or waveguide 3, each having a fiber core denoted 4 and 5, respectively. The function of the optical fibers could also be implemented using other sorts of waveguides in glass material or semi-

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conductor material. Considering optical fibers, there could
be used two separate fibers as depicted in figure 1 or a
single fiber with a dual core could be used. The cores 4, 5
are provided with a first deflector 6 and a second deflec-
5   tor 7, respectively. Each deflector 6 and 7 comprises two
superimposed blazed fiber Bragg gratings oriented at right
angles with respect to each other. The deflectors 6, 7 de-
flect light impinging upon the two superimposed fiber Bragg
gratings into two anti-parallel beams. The deflector ele-
10   ment could also be implemented using other sorts of deflec-
tors, e.g. simple blazed fiber Bragg gratings, angled con-
centrated mirrors, such as metallic mirrors dielectric step
mirrors, or angled Bragg reflectors, such as angled dielec-
tric stack mirrors or blazed-grated waveguides. The switch
15   element shown in the figure further comprises two external
mirrors 8 and 9, forming an external Fabry-Perot type reso-
nator 10. The external resonator is positioned so that the
deflectors 6, 7 are enclosed within the resonator. The ex-
ternal Fabry-Perot resonator may also be implemented using
20   concentrated mirrors, such as metallic mirrors or dielec-
tric step mirrors, or Bragg reflectors, such as dielectric
stack mirrors or grated wave-guides. Finally the switch
element includes actuators 11, 12 operative to change the
optical length of the external resonator (the optical dis-
25   tance between the mirrors) to provide wavelength and phase
tuning of the switch element. The optical distance com-
prises the distance between the first external mirror and
the first deflector, distance between the first deflector
and the second deflector and the distance between the sec-
30   ond deflector and the second external mirror. Each of the
distances may be arranged to be individually tunable. The
actuators 11, 12 could be implemented using various sorts
of actuation methods for changing the optical path length:

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Actuation by changing the geometrical path length, such as
piezo or electrostatic actuation, or actuation by changing
the refractive index, such as current injection or reverse-
bias actuation in the p-n junction of a semiconductor.

5   The external resonator provides a spectrally selective
enhancement of light energy in the region intended for
switching. This is in order to select the particular chan-
nel of interest for switching. This is while leaving other
channels substantially unaffected. The external resonator
10   forms a Fabry-Perot cavity in which the selected light
wavelength experience spectral resonance. The spectral
resonance is due to constructive interference by multiple
reflections between the first and a second external mirror.
The optical path distance between the external mirrors is
15   in the following called the cavity optical length. The cav-
ity optical length multiplied by a factor of two equals a
multiple integer number of wavelengths, for the selected
channel. Thus, the amount of switched light energy for the
channel external resonator depends on the matching of the
20   wavelength to the Fabry-Perot resonance and on the values
of reflectance of the external mirrors. Thus, the external
mirror provides spectral selection. This is in the follow-
ing denoted the wavelength tuning mechanism. The wavelength
tuning mechanism is a sub product of the Fabry-Perot mecha-
25   nism.

        The deflectors 6, 7 provides the coupling of light en-
ergy from the first optical fiber 2 to the second optical
fiber 3, which is enhanced for the chosen channel by the
wavelength tuning mechanism of the external resonator.
30   Here, the switching is obtained as follows. First, light in
the first optical fiber 2 is deflected by the deflector 6
into the external resonator 10. Second, resonance of the
selected wavelength is achieved due to the Fabry-Perot

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resonator. Third, a second deflection of the chosen channel
from said external resonator by the second deflector 7 into
the second optical fiber.

Another underlying mechanism, in the following denoted
5   the phase tuning mechanism, is provided by the innovative
use of superimposed blazed gratings. This provides a means
to obtain the phase tuning mechanism in addition to the
wavelength tuning mechanism.

The phase tuning mechanism provides a means of turning
10   the switch element from a "bar" to "cross" state. This
without the need employ the wavelength tuning mechanism to
detune (change) the resonant wavelength. Thus, in a cross-
state of the switch element the selected wavelength is cou-
pled from the first to the second optical fiber. In the bar
15   state, the selected wavelength is not coupled to the second
fiber, but continues to propagate in the first fiber. The
switch element can also be tuned, by the phase tuning
mechanism, to a 'broadcast' state, being an intermediate
state between the bar and cross states. In the broadcast
20   state, the resonant wavelength from the input of the fiber
is dropped just in fraction to the second fiber, while the
remainder of the light continues to propagate in the first
fiber. Thus, the amount of switched light energy does de-
pend on the phase tuning mechanism. This since the amount
25   of switched light energy does depend also on the phase re-
lations in interference, which in turn depends of the fol-
lowing optical path distances: the distance between the
first external mirror and the first deflector, the distance
between the first deflector and the second deflector, and
30   the distance between the second deflector and the second
external mirror.

The following set of physical properties of the
switch element should be considered as a set of critical

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design parameters of the device. In order to achieve a
certain free spectral range of the device, i.e. leaving
the spectral properties of the light unchanged except for
the spectral region of interest in which the switching
5. device is to operate, a certain maximum geometrical dis-
tance between the mirrors must be set. The radii of cur-
vature of the mirrors can be used for compensation of an
asymmetry of the optical field distribution inside the
cavity, and can also be used for enhancing the coupling
10 efficiency and overall performance of the switching de-
vice, e.g. by compensating for certain geometrical limi-
tations of the cavity. The angle of out- and in-coupling
of the optical modes in the fibers is to be chosen as
close as possible to the perpendicular direction of the
15 symmetry axis of the fiber, still leaving the cone of
out- or in-coupled light free from the perpendicular di-
rection. In case the perpendicular direction is contained
within the cone of out- or in-coupled light, a spectral
degeneracy of the coupling efficiency of the switch will
20 occur, causing an unwanted enhancement of coupling effi-
ciency in a region of the spectrum of operation of the
switch. The tilt of the mirrors relative to each other
(deviation from an all-parallel configuration of the cav-
ity mirrors) control the spectral width of the coupling
25 between the optical modes in the fibers. The more paral-
lel the mirrors are to each other, the narrower and en-
hanced the spectral coupling efficiency will be, and,
vice versa, the more tilt relative each other the mirrors
possess, the wider and weaker the spectral coupling effi-
30 ciency will be. The length of the blazed gratings of the
optical fibers determines the effective length of inter-
action between the modes propagating in the optical fi-
bers. The desired length of the blazed gratings is deter-

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mined from the coupling strength of the gratings and the
desired angular width of the out- or in-coupled light
cone. For gratings possessing high coupling efficiencies,
a short grating length should be chosen in order not to

5   cause unwanted coupling back into the original fiber at
the end of the grating. Similarly, for weak gratings, the
grating length should be chosen long enough in order to
ensure that the light coupled out from the first fiber is
fully coupled into the second fiber. In addition, the

10   length of the gratings determines the angular width of
the cone of out- or in-coupled light of the fibers. The
longer the grating length, the more narrow the cone of
out- or in-coupled light; and vice versa. The angular
width of the out- or in-coupled light of the fibers, as

15   determined by the grating length as previously described,
determine how close to the perpendicular direction of the
fiber one may choose out- and in-coupling light cone. The
more narrow the cone is, the more close to perpendicular
one may choose the direction of out-coupling, hence in-

20   creasing the coupling efficiency between the interacting
optical modes in the fibers. In order to achieve a high
coupling efficiency between the propagating optical modes
in the fibers, the reflectivities of the mirrors of the
cavity should be chosen as high as possible. Imperfec-

25   tions of the mirror surfaces will cause scattering of the
reflected optical waves inside the cavity, hence effec-
tively causing a loss of power and a decrease in coupling
efficiency. The strengths of the gratings are related to
the length of the gratings.

30   In figure 2 a cleaning element 20 is depicted. Such an
element may be desirable to incorporate into switch devices
to 'clean' a light wavelength channel from remaining signal
content, down to a very low signal power level. Channel

cleaning may be required in order to compensate for a non-
ideal switching element. This since the switching element
may not be able to completely switch all signal content in
a light wavelength, when aiming to drop this light wave-

5   length from the first to the second waveguide. The first
waveguide should be cleaned from the unintentionally re-
maining signal content. This in order to allow re-use of
the same wavelength for another data signal, while avoiding
coherent mixing of the old and the new data signals sharing

10 the same wavelength position. The cleaning element may be
implemented in the same manner as the switch elements.
Here, however, a second waveguide is not required to pick
up out coupled light.

Yet another arrangement may be used to obtain a

15 spectrally clean switching element. In this arrangement,
two switch elements are used in a serial configuration as
subsequently described. In the spectrally clean switching
configuration, the first waveguide of the first basic
switch element is connected to the first waveguide of the

20 second basic switch element via a waveguide in which one
may control the optical path length over which the light
propagates from the first to the second basic switch ele-
ment. The second waveguide of the first switching element
is similarly connected to the second waveguide of the

25 second switch element via a waveguide whose optical path
length may, but not necessarily have to, be possible to
control. The interconnecting waveguides, at least one of
which possess the possibility of controlling the optical
path length experienced by a propagating light wave, are

30 together denoted as the enabling element of the spec-
trally clean switching element. As subsequently de-
scribed, the role of the enabling element is to turn on
or off the switching of a particular spectral region of

the light, as determined by the configuration of the two

basic switching elements. The two basic switch elements

should, in the case of constituting the two switching

components of a spectrally clean switching element, be

5   designed in such a way that only fifty percent of the

light in the first waveguide of each basic switch element

is coupled over to the second waveguide of respective ba-

sic switch element.

The principle of operation of the spectrally clean

10   switching element is as follows. As fifty percent of the

power of the light in the first waveguide of the first

basic switch element is coupled over to the second

waveguide, passing through the waveguides of the enabling

element, and being recombined with the remaining fifty

15   percent of the light power in the second basic switch

element, the relative phase of the light waves, when re-

combined in the second switching element, will determine

whether constructive or destructive interference occur in

the blazed gratings of the second basic switch element.

20   When the relative phase shift of the light waves in the

waveguides, when entering the second basic switch element

from the enabling element, is a multiple of 2*pi, the

second basic switching element will cause the remaining

fifty percent of the light power in the first waveguide

25   to be coupled over to the second waveguide, hence causing

a switching from the first to the second channel of the

spectrally clean switching element. In this case, the

enabling element acts as an optical interconnect leaving

the relative phase of the light waves invariant, and the

30   spectrally selective switching is performed in the same

manner as in the case of a basic switching element nomi-

nally designed for switching one hundred percent of the

optical power in a certain spectral region. On the other

hand, when the relative phase shift between the channels
is pi plus a multiple of 2*pi, the second basic switching
element will cause the fifty percent light power in the
second waveguide to be coupled back into the first

5   waveguide, hence in the first case, for a N*2*pi relative
phase shift, a constructive interference is experienced
in the second waveguide of the second basic switching
element, while in the second case, for a (2*N+1)*pi rela-
tive phase shift, a constructive interference is instead

10 experienced in the first waveguide. Using the enabling
element as an on/off control (enabler) of the switch, the
described principle of operation allows the basic switch
elements to be reconfigured or adjusted in the off state,
with a N*2*pi relative phase shift between the waveguides

15 in the enabling element, without affecting the light
waves in any of the neighboring wavelength channels. As
the reconfiguration or adjustment of the basic switch
elements is done, the spectrally clean switching element
is put into operation by tuning the relative phase shift

20 between the waveguides to (2*N+1)*pi. As the phase shift
is tuned, the optical power coupled from the first to the
second waveguide of the spectrally clean switching ele-
ment will gradually increase from nominally zero to one
hundred percent. The spectral region in which the switch-

25 ing is performed is confined to the interval as deter-
mined by the configurations of the two basic switching
elements, and since these are kept constant during the
tuning of the enabler, adjacent wavelength channels are
left unaffected by the spectrally clean switching ele-

30 ment.

Several mechanisms may be considered for achieving a
relative phase shift between the light in the two
waveguides of the enabling element. One way of causing

the optical path length in one waveguide to change is to
apply mechanical stress to the waveguide. Other means of
changing the optical path length is to employ electro-
optical effects, magneto-optical effects, or by other

5   means, chemically, mechanically, or electro-magnetically,
changing the refractive index of the core and/or cladding
of the waveguides of the enabling element. The enabling
element may also be incorporated in the first or second
basic switch element by applying an electro-optical layer

10   to any of the mirrors of the cavity, and applying a
weakly reflecting mirror to the electro-optical layer, in
a setup as for a dynamically reconfigurable Gires-
Tournois interferometer.

In may be desired to incorporate polarization manage-

15   ment, since the switch element and the cleaning element in-
herently is unable to properly handle light with arbitrary
polarization state. Proposed devices includes Faraday mir-
ror polarization handler, quarter-wave plate mirror polari-
zation handler, dual path polarization handler and serial

20   twist polarization handler.

Figure 3 shows an add-drop device where polarization
management is obtained by having positioned between a cir-
culator 30 and a pair of Faraday mirrors 31, an array of
switching elements 32. Input light thus passes the circula-

25   tor of the first waveguide. In the switch element, for the
selected wavelength, i.e. the light wavelength which is
resonant to the external resonator, when in cross state
(i.e. when the phase tuning mechanism is used to achieve
the cross state) one polarization component of this light

30   wavelength is switched over to the second waveguide. Since
the switch element is polarization selective, the remain-
ing, perpendicular, polarization component is unaffected by
this switch element, and passes through to the Faraday mir-

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ror of the first waveguide. Here, the light wavelength is
back reflected. However, the polarization component has
been rotated by 90 degrees by the Faraday mirror. Thus,
when again reaching the same switch element, the back-

5   reflected light now has the proper polarization state to be
switched to the second waveguide. Due to the properties of
the switching element, after having been coupled to the
second waveguide, the different switched portions of the
light wavelength will have the same polarization state but

10   travel in opposite directions. Also, coherent mixing can be
avoided within the switch element by proper design. When
leaving the switch element, the polarization component,
which was directly coupled from the first waveguide to the
second waveguide, will be back reflected and rotated 90 de-

15   grees in the Faraday mirror of the second waveguide. This
polarization component then passes the switch element with-
out experience switching, since it has now been rotated to
the insensitive polarization state, and following propa-
gates to the circulator of the second waveguide. However,

20   the polarization component, which was coupled from the
first waveguide after Faraday mirror back reflection and
rotation to the second waveguide, will be propagating di-
rectly to the circulator of the second waveguide. The two
polarization components thus again combine in the second

25   waveguide, as two orthogonal states of polarization. It is
required that the optical paths between the switch element
and the Faraday rotators of first and second waveguides are
matched. This is in order to avoid polarization mode dis-
persion and also to avoid polarization dependent loss.

30   In the case of the Faraday mirror polarization han-
dler, it is not required for polarization states to be
maintained when light is propagating in waveguides between
the switching element and the respective Faraday mirrors.

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This is due to reciprocity. It is sufficient that the po-
larization properties of the fiber, does not alter within
the time it takes for light to propagate from the switching
element to the respective Faraday mirror and back again.

5   This condition is typically fulfilled, since the light
propagation time is typically on the order of picoseconds,
while the polarization changes are typically very much
slower.

        In figure 4 the Faraday mirror is replaced with a com-
10   mon quarter wave plate mirror 41. For a quarter-wave plate
mirror polarization handler, the polarization state must be
substantially maintained between the switching element(s)
and the quarter-wave plate with mirror. Also, the polariza-
tion state for a switched wavelength must be substantially
15   linear after having dropped one polarization component.
Further, the remaining polarization component must be
aligned at 45 degrees with respect to the optical axis of
the quarter-wave plate. This in order for the quarter-wave
plate and the mirror to return the remaining polarization
20   rotated 90 degrees and thus switched by the element at the
return path. The advantage with the quarter-wave plate mir-
ror polarization handler is that a common quarter-wave
plate and mirror could be more easily employed for both the
first and second waveguide. This is not so easily imple-
25   mented when using Faraday rotator elements in the Faraday
mirror handler.

        In figure 5 an add-drop device using dual path polari-
zation handler is depicted. This is obtained by having the
polarization of the input light propagating in the first
30   waveguide split by a polarizing beam splitter 51 into two
components, before the switching elements. Thus each po-
larization state is injected into a respective first
waveguide, which is substantially polarization maintaining.

Following, each polarization component is handled in its
respective first waveguide. Each first waveguide contains
one or more switching elements. After the switching ele-
ments, the respective first waveguides are again combined

5   using another polarizing beam.splitter 52 to a common first
waveguide. Thus, for light wavelengths, which are not
switched, the polarization components are again combined
after having propagated through the switching elements. The
arrangement of the second waveguide is a mirror image of

10   the first waveguide. Thus, for light wavelengths which are
switched, the polarization components are again combined
after having propagated through the switching elements. The
advantage of the dual path polarization handler is that it
works in transmission, and thus does not require circulator

15   components. A disadvantage with the dual path polarization
handler is that it requires at least two switching elements
for each wavelength, since each of the two polarization
components requires a dedicated switching element. Also,
the polarization has to be substantially maintained, con-

20   sidering all waveguides. Further, if employing a switch
controller, both polarization components might need to be
controlled independently.

In figure 6, an add-drop device using serial twist po-
larization handling is shown. This is obtained by having

25   the polarization of the input light propagating in the
first waveguide, propagating to a first series of switch
elements for different light wavelengths. The first array
of switch elements then acts upon one of the polarization
components. This in order to either switch or not switch a

30   particular light wavelength. Then, the remaining polariza-
tion component, to be acted upon, is rotated (twisted) sub-
stantially 90 degrees, relative to a second array of
switching elements. Following, the remaining polarization

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component is acted upon by a second array of switch ele-
ments. For the serial twist polarization handler, the rota-
tion (twisting) of the remaining polarization component
could be accomplished by twisting the main polarization

5   axis of both the first and second waveguides. Here, the
first and second waveguides are required to substantially
maintain the polarization state of the propagating light
wavelengths. The advantage of the serial twist polarization
handler is that it works in transmission, and thus does not

10   require circulator components. A disadvantage with the se-
rial twist polarization handler is that it requires at
least two switching elements for each wavelength, since
each of the two polarization components requires a dedi-
cated switching element. Also, the polarization has to be

15   substantially maintained, considering all waveguides. Fur-
ther, if employing a switch controller, both polarization
components might need to be controlled independently.

          Figure 7 shows an integrated switch device 70, incor-
porating the inventive optical switch. The switch device 70

20   includes a switch controller 71 that monitors the light
output of the switch elements and uses this information as
a feedback for adjustment. Light is coupled from the input
optical fibers via tap devices 72. Which input fiber to be
measured is then chosen by the mechanical switch 73. In

25   general, a switch controller measures the output light
wavelengths and possibly also the input light wavelengths
for the first and second waveguides of the switch ele-
ment(s). The switch controller uses this information to
control the states of the actuation elements, such that the

30   desired signal power is obtained for the respective output
light wavelengths.

          In order to fully handle a given switch application,
the corresponding implementation of a full-featured inte-

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grated switch device, is desirable. Such an integrated
switch device may consist of an assembly of switch ele-
ments, polarization handlers, cleaning elements and switch
controllers.

5   In figures 8-12 a number of types of basic device im-
plementations for the switch mechanism are shown. Such a
device is referred to as an integrated switch device. An
integrated switch device may consist of an assembly of un-
derlying elements, such as switch elements, polarization

10   handlers, cleaning elements and also switch controllers.

In figure 8 a wavelength-selective 2x2 fiber switch 80
is depicted. It is built by underlying devices, of the
types add-drop device 81 and cleaning device 82. This inte-
grated switch device is denoted the two-fiber switch de-

15   vice.

Note that when the two-fiber switch device employs the
dual path polarization handler, the number of polarizing
beam splitters can be reduced. This is by splitting the po-
larization components at the input ports of the two-fiber

20   switch device, and keeping them separated until the output
ports, where polarizing beam splitters are used to again
combine the polarization components. Here, in order to
avoid polarization mode dispersion, the optical paths have
to be carefully matched for the respective polarization

25   components.

Note that when the two-fiber switch device employs the
serial twist polarization handler, the number of polariza-
tion twisters can be reduced. This is by first handling
dropping, cleaning and adding of one of the polarization

30   components, then employ a polarization twister, and then
second dropping, cleaning and adding the remaining polari-
zation component. Here, in order to avoid polarization mode

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dispersion, the optical paths have to be carefully matched
for the respective polarization components.

In figure 9 a multiplex device 90 is depicted. This
device multiplexes/de-multiplexes one ingress fiber from/to
5   several egress fibers.

In figure 10 a matrix device 100 is depicted. The de-
vice type uses N input fibers to N output fibers, where the
input fibers are crossed with respect to the output fibers.
The N input fibers are linked to the N output fibers in N*N
10   nodes. The linking occurs via switch elements. This switch
device is referred to as a matrix switch device. For the
matrix switch device, a configuration could be chosen where
light wavelengths are exchanged between the fibers via two-
fiber switch devices. Note that when the matrix switch de-
15   vice employs the dual path polarization handler, the number
of polarizing beam splitters can be reduced. This is by
splitting the polarization components at the input ports of
the matrix switch device, and keeping them separated until
the output ports, where polarizing beam splitters are used
20   to again combine the polarization components. Here, in or-
der to avoid polarization mode dispersion, the optical
paths have to be carefully matched for the respective po-
larization components. Note that when the matrix switch de-
vice employs the serial twist polarization handler, the
25   number of polarization twisters can be reduced. This is by
first handling dropping, cleaning and adding of one of the
polarization components, then employ a polarization
twister, and then second dropping, cleaning and adding the
remaining polarization component. Here, in order to avoid
30   polarization mode dispersion, the optical paths have to be
carefully matched for the respective polarization compo-
nents. For the matrix switch device, alternatively, another
configuration could be chosen where the input and output

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fibers are perpendicularly oriented relative to each other
in the basic switch elements. Half-wave plates could then
be inserted in the switching elements, between the input
fibers and output fibers. This since the switched polariza-

5   tion component needs to be rotated 90 degrees to be ori-
ented perpendicular to the propagation direction of the
output fiber.

     Figure 11 depicts a switch device, which uses multiple
cascaded stages of two-fiber switch devices. This sixth

10   switch device will be referred to as a the multi-stage
switch device.

     Figure 12 depicts a close network type switch device
using two-fiber switch devices.

     The embodiments of the present invention that are

15   described above and schematically shown in the drawings
are not intended to limit the scope of the protection
sought. On the contrary, any person skilled in the art
will realize that a number of different embodiments, and
modification of the embodiments shown and described, are

20   conceivable within the scope of the invention. The scope
of the invention is defined in the appended claims.